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the copper being the negative metal, the galvanic action is against the *iron*. We admit this; but, if the coating of copper is perfect, this cannot be the case, as no galvanic action can possibly take place unless the metals are both together exposed to the fluid. The resisting qualities of copper to oxidation, when exposed to water and vegetable acids, render it a valuable protection to iron under all ordinary circumstances.

For ornamental work copper is best adapted, as it takes a beautiful bronze, either by exposure to the atmosphere or by artificial means. A great saving might also be effected by casting statues and other ornamental work in iron, and afterwards coppering it. The iron castings of the Colebrook Dale Works cannot be surpassed for sharpness and effect.

Works of art in iron, plasters, terra cotta, wood, and other substances, may be thus made to resemble antique bronzes, and the process may be advantageously adapted to machinery, especially that which is exposed in damp situations.

We may add that iron either zincd or coppered solders with great facility.

No. III.

ON THE SMOKELESS ARGAND FURNACE OF CHARLES WYE WILLIAMS, Esq.

By HENRY DIRCKS, Furnace Architect and Engineer.

Nov. 22, 1843.

THOMAS HOBLYN, ESQ., F.R.S., V.P., IN THE CHAIR.

THERE can be no doubt, from the great advancement made of late years in the attainment of a practical know-

ledge of the chemistry of combustion, that we are on the eve of an important change in the mode of conducting the combustion of coal, in steam-engine boiler and other furnaces, to avoid the loss of its gaseous products, for heating purposes. It must be admitted, indeed, that manufacturers are becoming more than ever alive to the merits of this subject; the information that chemical science affords, demonstrating a positive loss, as evidenced by the formation of dense volumes of smoke, and the consequent very partial combustion of the coal-gas and carbonic oxide, generated in the furnace; no provision being made for the combustion of these gaseous products of the fuel in furnaces as ordinarily constructed.

No one has ever doubted the discomfort, if not positive insalubrity, of an atmosphere surcharged with coal-smoke. In our own country we find the amiable Evelyn in his "*Fumi Fugium*," published so early as 1661, giving an elaborate account of "the inconvenience of the air and smoke of London;" proposing as a remedy the entire removal of the manufactories. There seems to be no mitigation of the nuisance in London, comparing what Evelyn says of the seventeenth with what we know to exist in the nineteenth century; and, as a single illustration, the following fact may be adduced, as stated by Dr. D. B. Reid, in his evidence before the Parliamentary Committee on Smoke Prevention, July 1843. He says: "The impurity produced by the imperfect combustion which generates smoke is of a much more offensive nature, in particular by producing those black portions of soot that every one is familiar with, and which annoy us (for instance at the houses of parliament) to such an extent that I have been under the necessity of putting up

a veil, about forty feet long and twelve feet deep, on which, on a single evening, taking the worst kind of weather for the production of soot, we can count occasionally 200,000 visible portions of soot excluded at a single sitting. We count with the naked eye the number of pieces entangled upon a square inch.”—*Report*, p. 28.

That an unseemly nuisance of this nature, interfering as it does with the purity of the air, should, after existing for nearly two centuries, have excited the attention of the legislature, and called into exercise mechanical ingenuity, is only naturally to be expected. It is, however, to the latter alone we shall bend our attention.

To a casual, uninformed observer, nothing can appear more simple or easy than, by a little contrivance, to completely *burn* and get rid of all the smoky vapour usually observed escaping from a chimney-top. Fascinated by the apparent facility of attaining this long-desired object, an infinite number of mechanical arrangements have been projected, and much labour in vain has been expended in following this *ignis fatuus*. Nothing can be more plain than that all *merely mechanical* plans, constructed irrespective of certain known chemical conditions to be attained, must lead to an erroneous application of talent. Until we know the end to be attained, how can we, by any thing short of blind chance, stumble on the best method of favouring such a wonderful, complicated, yet exact, chemical process as that of combustion? The consequence has been what might be expected; ingenious mechanics and others who have attempted “smoke-burning,” have, by running counter to nature, opposed her immutable laws, and been met only by disappointments at every step of their progress.

The Society of Arts has for upwards of sixty years

published a premium for a plan for the "Prevention of Smoke." Offering their gold medal "For a method superior to any in use, and verified by practice, of preventing the emission of dense smoke from the chimneys of furnaces and fire-places."

Watt's celebrated patent for *smoke-burning* bears date June 1785; the object of his invention being to cause the smoke to pass "*through, over, or among, fuel which has already ceased to smoke, or which is converted into coke, charcoal, or cinders, and which is intensely hot.*" The inutility of this "intense heat," apart from other considerations, when applied to gaseous combustion, is successfully proved by Mr. C. W. Williams in his treatise on the *Combustion of Coal*. "This erroneous notion," he says, "of the supposed combustion of the gases (or smoke), by bringing them into contact with a mass of 'glowing coals,' appears to have originated with Watt; and, having been adopted by Tredgold and others, has since passed into a recognised principle; thus by inducing a conventional mode of speaking on the economy of fuel, the error has been perpetuated. It appears strange," he goes on to say, "that, while so many have taken this as their text, or adopted it as their starting-point, none of these inventors have examined, or even doubted, its correctness. Yet any chemical work of authority would have informed them of the well-established fact, that *decomposition*, not combustion, is the result of a high temperature applied to the hydrocarbon gases; that *no possible degree of heat can consume carbon*, and that its combustion is merely produced by, and is, in fact, its *union* with oxygen, which latter, however, they take little care to provide."—P. 127.

Dr. Kane, of Dublin, in a laboratory process, well

describes, on a small experimental scale, what “smoke-burners” effect on the large scale of the furnace by their unscientific adjustments. He states, that “when olefiant gas is passed through tubes heated to bright redness, it deposits half its carbon, and, without changing its volume, is converted into light carburetted hydrogen. If it be frequently passed backward and forward through the tube, it deposits *all* its carbon, and the residual gas (the volume of which is *doubled*) is found to be pure hydrogen.”

Now when, in the furnace, it is brought to this latter stage by a “smoke-burning” process for bringing what was originally coal-gas into contact with a body of “*glowing incandescent fuel*,” the conditions of the furnace, and this laboratory experiment are analogous; a deposition of carbon results, the carburetted hydrogen undergoing decomposition (not combustion), hydrogen gas is produced, and uniting with what oxygen the close furnace affords, vapour of water is formed, of course invisible, or nearly so. Confining our attention to this single operation, we trace in three processes:—

1. By smoke-burning—an escape of nearly invisible *steam*.
2. By the smoke not being burnt—an escape of *black smoke*.
3. By a judicious admission of atmospherical oxygen to satisfy the requisite chemical conditions—an escape of *carbonic acid*, mixed with some *steam*, and both wholly or nearly invisible.

The first process is a *loss* by a chemical decomposition; the second is a *loss* by what we understand by im-

perfect or incomplete combustion ; the third, or correct chemical process favouring the conditions required for entire combustion, is attended with a saving, the amount of oxygen taken up being greater in the third than in either of the other methods ; and which, though not strictly an invariable rule, is, nevertheless, a safe criterion of superior benefit gained. This is so nearly an axiom with chemists, that Dr. Kane observes : “ The quantity of heat evolved in the burning of any body is proportional to the quantity of oxygen absorbed, and it is hence the interest of the operator to use as much oxygen as possible, instead of the reverse.”

It is not the object of this paper to enter at length into any chemical details, otherwise some curious and interesting facts might be stated, shewing the source of loss by the absorption of heat to effect smoke-burning, which, when attained, is again a further loss. Indeed, the whole process of combustion, complex as it may to some appear, is quite intelligible and comprehensible in all its main bearings when chemically considered.

How, therefore, any one totally ignorant of the constitution of the atmosphere, the composition of coal, the decompositions effected by combustion, and the recompositions which follow, is to provide the needful mechanical means for balancing the one against the other, and assist rather than thwart the course of nature, does not appear, neither is it a likely accident to befall any who are so situated. But, once having a certain end in view, the means to the attainment of that end may depend much upon mere mechanical skill. The desire to burn SMOKE led to a variety of forms of furnaces, grates, bars, and even boilers, each inventor striving to burn the largest quantity of fuel with the least quantity of

air. On the part of Mr. Williams, on the contrary, his attention was entirely directed to the combustion of the great body of GAS, which he considered must obtain, in ordinary furnaces, a very limited supply of air. With him, therefore, it was a question how to get *air* to the gas, or *gas* to the air. So completely was he imbued with a conviction of the errors of the *smoke*-consuming principle, that he states, "The mere enunciation of a plan for *consuming smoke* is *primâ facie* evidence that the inventor has not sufficiently considered the subject in its chemical relations." And he does ample justice to the memory of Watt, when he says, "It is not his fault that the errors he committed should continue to be repeated; he would have been among the first to benefit by and apply the more correct principles of combustion developed by the rapid improvement of chemical science in subsequent years." Nothing, certainly, can be more ill judged than to trammel the progress of improvement by that reverential reliance on the authority of great names rather than go with the current of more advanced knowledge, "restricting rather than extending the realms of science."

Mr. Galloway, a popular writer on the steam-engine, nearly twenty years back, in taking notice of the "smoke-burning" expedients of his day, makes a remark which, whatever may have been thought of its justice at the time, certainly agrees with all later experience, and offers one among many convincing proofs of the instability of ingenious attempts founded on unsound principles. "Numerous," says he, "were the plans tried to consume the smoke, and, although some were partially successful, they were found generally either inconvenient or occasioning a greater consumption of fuel, so as to

lead to no advantageous result to the proprietors, however the public might be benefited by their adoption. These circumstances led to the abandonment of most of the plans, except in those instances wherein the proprietors were compelled to their adoption and continuation by indictments for public nuisances."

In 1839, Charles Wye Williams, Esq., of Liverpool, patented a peculiar mode of admitting air to furnaces, a plan better known as the smokeless Argand furnace, from its near approach to the principle of the Argand gas lamp. Mr. Williams is also the author of the well-known treatise on the "Combustion of Coal," a work of great merit, and, indeed, the only one on the subject in our language. Mr. Williams in his treatise gives a concise view of the chemical theory of combustion; and by his furnace has clearly demonstrated the successful application of known chemical principles to practical purposes. Lest, however, I should be misunderstood by any who may suppose that this statement is not strictly correct, imagining that Mr. Williams entertains a theory entirely his own, a reference to his own observations on this head will at once clear up any doubt. He says, "In undertaking myself to lead others, and to avoid the imputation of presumption, I observe, *in limine*, that I do not affect to give *any new view of the nature of combustion*, much less do I make *any claim to discovery*." No language can be clearer; therefore those who dispute the principles he has laid down are not so much disputing Mr. Williams's doctrines, as they are finding fault with the fundamental laws of chemistry itself.

To proceed with the quotation, Mr. Williams adds: "What I take credit for is the practical application, on the large scale of the furnace, of those chemical truths

which are taught by the ablest chemist of the day, and so well known in every *laboratory*. I also take credit for bringing together the detailed and scattered facts and illustrations of such authorities as bear on the subject before us, and of so arranging and applying them as will, I trust, enable practical men, without going deeper into the science than is compatible with their time and other avocations, to understand that part which chemistry has to act in the construction, arrangements, and working of our furnaces." Mr. Williams has shewn much originality not only in his writings, but also in his illustrative diagrams, given with a view of exemplifying the atomic theory of Dr. Dalton, and familiarising to the less informed that important doctrine of chemical science; and, from this subject being limited to the *Combustion of Coal*, the index to the after combinations, in accordance with the Daltonian theory, is very simple.

When satisfied on this head, the next subject of inquiry is the diffusion (not separation) of gases; that process by which a light gas, as hydrogen, will not remain permanently on the surface of the dense gas, carbonic acid, even though separated by a diaphragm of plaster of Paris; this mingling, this intermixture of the gases the one with the other, until a portion of the hydrogen has descended and become incorporated with the carbonic acid, and *vice versâ*, is an important chemical law, but it is, as thus conducted, an exceedingly slow process; agitation, pressure, the driving of one gas into the other in jets, as gas is pressed through the apertures of the Argand burner, are all means by which the process of perfect diffusion (incorporation) is obtained, only with considerable facility and despatch. Now as, in the operations of the furnace, *time* is an object

of the first consideration, Mr. Williams bent all his attention on ascertaining the most available means for attaining this incorporation of the air and impure gases in the furnace.

In his treatise Mr. Williams has well explained the successive steps by which he arrived at the happy contrivance and simple arrangements of the Argand furnace. He remarks that :—" In looking for a remedy for the evils arising out of the hurried state of things which the interior of a furnace naturally presents, and observing the means by which the gas is effectually consumed in the Argand lamp, it seemed manifest that, if the gas in the furnace could be presented by means of *jets* to an adequate quantity of air, as it is in the lamp, the result would be the same; namely, a quicker and more intimate mixture and diffusion, and, consequently, a more extensive and perfect combustion. The difficulty of effecting a similar distribution of the gas in the furnace by means of jets, however, seemed insurmountable; one alternative alone remained, namely, that since the gas could not be introduced by jets into the body of air, *the air might be introduced by jets into the body of gas.*"

The whole theory being thus far perfected, and every way strictly agreeing with known facts and laboratory experiments, it remained to be ascertained how far chemical theory was available in practice with large steam-engine boilers [the great and sole object of Mr. Williams's investigations]; feeling deeply concerned in the inquiry, from his intimate connexion with two extensive steam-boat companies, and how far he was qualified for the task, his early education under Dr. Higgins, the father of the Atomic theory (though elaborated by Dr. Dalton, and, as appears most likely, with him original);

his chemical knowledge, further enlarged while conducting an extensive bleaching establishment, and not less his chemical writings, offer the best, and certainly most conclusive evidence.

While making these remarks, it may be as well to observe that Mr. Williams's attention has been mainly directed to marine-boilers. The material difference between the construction of marine and land engine-boilers is very considerable; there is, certainly, some approximation between a marine and Cornish boiler, the furnace of both being within the boiler and surrounded by water: not so, however, with waggon and round or cylindrical boilers; they have the furnace underneath them, set in brickwork. The only reason for my noticing this apparently trifling particular is to observe that, although Mr. Williams writes in pretty general terms, it is easy to understand how his long experience with the one class of boilers would lead to some trifling disparity, otherwise of no moment than when unfairly stretched to make his statements and practice appear contradictory. What I allude to is, a foolish and almost unaccountable statement that Mr. Williams admits air at the *bridge* in jets—always at the *bridge*, and nowhere else. It will, perhaps, scarcely be credited that, with the patent specification before them, any one would be so regardless of facts as to make such a statement; the precise words employed being, “I do not confine myself to the particular number, dimension, or *situation* of the several parts.” It so happens, that in marine and Cornish boilers no alternative is left but to put the apparatus behind the bridge, but in almost every other plan of boiler it is a matter of choice; while in some furnaces without boilers, as annealing furnaces, there is, again, no choice but to give

the air before the bridge. It would, indeed, have been strange, if, while advocating the principle of diffusion, he should thus have trammelled his theory and practice by a needless limitation.

Without going into lengthy chemical details it may suffice to observe, to shew, and impress on the memory, the necessity for this division of the air, that at the time coal-gas is being evolved, every cubic inch of that gas requires ten cubic inches of air to obtain therefrom the requisite saturating dose of oxygen: this Mr. Williams further illustrates by his chemical diagrams; or the process may be given thus:—

BEFORE COMBUSTION.	ELEMENTARY MIXTURE.		PRODUCTS OF COMBUSTION.
<i>Weight.</i>	<i>Atoms.</i>	<i>Weight.</i>	
8 Carburetted Hydrogen..	$\left\{ \begin{array}{l} 1 \text{ Carbon} \dots 6 \\ 1 \text{ Hydrogen} \dots 1 \\ 1 \text{ Hydrogen} \dots 1 \\ 1 \text{ Oxygen} \dots 8 \\ 1 \text{ Oxygen} \dots 8 \\ 1 \text{ Oxygen} \dots 8 \end{array} \right.$	$\left\{ \begin{array}{l} 6 \\ 1 \\ 1 \\ 8 \\ 8 \\ 8 \end{array} \right.$	$\left\{ \begin{array}{l} 22 \text{ Carbonic Acid.} \\ 9 \text{ Steam.} \\ 9 \text{ Steam.} \end{array} \right.$
144 Atmospheric Air	$\left\{ \begin{array}{l} 1 \text{ Oxygen} \dots 8 \\ 1 \text{ Oxygen} \dots 8 \\ 1 \text{ Oxygen} \dots 8 \\ 8 \text{ Nitrogen} \dots 112 \end{array} \right.$	$\left\{ \begin{array}{l} 8 \\ 8 \\ 8 \\ 112 \end{array} \right.$	112 Uncombined Nitrogen.
152	152	152	

Taken by volume, after the manner of Berzelius, the several gases of the furnace require, for the obtaining of sufficient oxygen:—

Bicarburetted Hydrogen, or Oiliant Gas	15 Volumes of Air.
Carburetted Hydrogen, or Coal Gas	10 ditto.
Carbonic Oxide, or Coke Gas	5 ditto.

Bearing in mind that the air and gas have to be incorporated, that no time must be lost, that we have here 15, 10, and 5 volumes of air to combine with one measure of each of the gases, can a doubt exist that, if we have these two æriform bodies in bulk, mixture will not be so intimate, perfect, and, above all, so rapid as when, instead of a single stream, there are some hundreds of small jets, or films of air, each entering a hot gaseous atmosphere, and mingling therewith,

producing most effective mixture,—what we may call gasified air, not crude air *and* gas, but the two in intimate union, well milled and mixed together,—a mechanical compound of chemical ingredients, highly combustible, and burning free from smoke, under proper adjustment? These preparatory conditions are analogous to the nature of gunpowder, the ingredients of which, loosely thrown together, however exact the proportions, are neither explosive nor yet are they gunpowder, until very intimately incorporated. The more nice and exact the contact of atom to atom, mechanically, the better; the *most* exact contact here is chemical, the result of combustion.

The mechanical arrangements of the Argand furnace are simple, without machinery; and, what is much in its favour, is capable of very general application to existing furnaces, without much detention or heavy alterations. The air-distributing apparatus is made of either brick or iron, and is placed in such part of the furnace as local circumstances render most available. By means of sight-holes the clear flame may be seen in the flues, and the lighting or extinguishing of the gas-flame follows the opening and closing of the apparatus. By a pyrometer formed of a rod of round iron, three-eighths or half-inch thick, the full length of the furnace, passing through the flue, screwed up tight at the back end, but protruding and moving through the brick-work in front, the temperature of the flues may be ascertained by making the expanding or contracting rod act on a proper lever as an index, moving over a suitable graduated scale. This is the form of the ingenious pyrometer of Henry Houldsworth, Esq. of Manchester, who has published his pyrometric tables, and who read a paper on this important subject at the meeting of the British Association when held in Manchester.

Mr. Williams's attention to furnaces naturally led him to the improvement of boilers, with a view to increased evaporative effect. This he has attained by studding the *outside* of boilers, where exposed in the flues, with iron pins three-quarters of an inch in thickness, and two or three inches long; they are made to taper, so that they may be safely driven from the inside, through holes drilled for the purpose.

This invention may not seem to have much relation to the furnace, nor has it so far as the subject of mere smoke nuisance is concerned, but it is an improvement which, though calculated to be of considerable benefit, requires a *smokeless* furnace to render it most efficient in its operation. The pins, if acted on by the elongated smoky flame of ordinary furnaces, would become collectors of soot, and their utility much diminished. To the manufacturer, then, to whom, abstractedly, smoke is a matter of no consideration, it is of consequence not to waste his gaseous fuel, not to decompose instead of burning it, and allow it to escape bodily, or improperly decomposed; it is also of consequence to him to prevent the fouling of his boilers or pans; and it is further of importance to have a smokeless furnace, if the additional improvement of increasing the heating surface, by using these conductor pins, is ever so distantly contemplated.

We certainly live in an age when discoveries and improvements are multiplied in such quick succession, that if we are sometimes doubtful of their truth we are, perhaps, as often in equal uncertainty whether we have yet attained the best form or application of what is new. Experience is the *best* criterion; and all experience informs us that effective practice, based on sound scientific principles, has always gained the ascendancy and been triumphant.